BONUS RETURN
Reducing Emissions by Turning Nutrients and Carbon into Benefits

https://www.bonusprojects.org/bonusprojects/the_projects/blue_baltic_projects/return

List of ecotechnologies
Agriculture and Municipal wastewater ecotechnologies for reusing carbon and nutrients in the Baltic

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X	PU	Public.
	PP	Restricted to other project partners.
	RE	Restricted to a group specified by the consortium.
	CO	Confidential, only for members of the consortium.

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EXECUTIVE SUMMARY

The current report is part of Deliverable 2.2 Work Package 2. The objectives of WP 2 are to summarise the evidence relating to reuse of carbon and nutrients using ecotechnologies through the use of systematic mapping and systematic review methodology.

In BONUS RETURN eco-technologies are understood as “human interventions in social-ecological systems in the form of practices and/or biological, physical, and chemical processes designed to minimise harm to the environment and provide services of value to society”.

The report summarises the initial systematic mapping of studies in two systematic maps on ecotechnologies in agricultural contexts and municipal wastewater contexts for reuse of carbon and nutrients. Please see the draft systematic map protocol for these mapping exercises appended to this document. This protocol outlines the planned methods for the maps and the procedures enacted during the preparation of this deliverable. The results of this coding are available in the additional files (BONUSRETURN_D.2.2_List of agriculture ecotechnologies.xlsx and BONUSRETURN_D.2.2_List of municipal wastewater ecotechnologies.xlsx).

1 INTRODUCTION

The degradation of the Baltic Sea is an ongoing problem, despite investments in measures to reduce external inputs of pollutants and nutrients from both diffuse and point sources. Available technological and management measures to curb eutrophication and pollution flows to the sea have not been adapted adequately to the contexts in which they are being applied. Furthermore, measures are often designed based on single objectives, thereby limiting opportunities for multiple benefits.

In addition, there is a general sense that measures to address the deterioration of the Baltic ecosystem are primarily technologically-driven and lacking broader stakeholder acceptance, and the "experts" who define these measures have little engagement with industry, investors, civil society and authorities. This problem is exacerbated by governance and management taking place in sectoral silos with poor coordination across sectors.

As a result, research shows that regional institutional diversity is presently a barrier to transboundary cooperation in the Baltic Sea Region (BSR) and that actions to achieve national environmental targets can compromise environmental goals in the BSR (Powell et al. 2013). The regional dimension of environmental degradation in the BSR has historically received weaker recognition in policy development and implementation locally. However, developments in recent years suggest a new trend with growing investments in environmental protection supporting social, economic, and territorial cohesion.

The BSR is an environmentally, politically and economically significant region and like other regions globally, its rapid growth needs to be reconciled with the challenges of sustainable development in a global setting that demands unprecedented reductions in GHG emissions. This poses a truly wicked problem exacerbated by the fact many of the challenges in BSR will also magnify in a changing climate. In order to navigate the uncertainties and controversies associated with a transformation towards a good marine environment, BONUS RETURN will enact an innovative trans disciplinary approach for identifying and piloting systemic eco-technologies.

Focus will be on eco-technologies that generate co-benefits within other interlinked sectors and which can be adapted according to geophysical and institutional contexts. More specifically, emphasis will be given to eco-technologies that reconcile the reduction of present and future eutrophication in marine environments with the regional challenges of policy coherence, food security, energy security, and the provision of ecosystem services.

1.1 Project Objectives

The **overall** aim of RETURN is to improve the adaptation and adoption of eco-technologies in the BSR for maximum efficiency and increased co-benefits.

The **specific objectives** of the project can be divided into 6 categories presented below. These categories are interlinked but for the purpose of providing a step-wise description, the following overview of each category proves useful. RETURN will:

1) Support innovation and market uptake of eco-technologies:

- Contribute to the application and adaptation of eco-technologies in the BSR through an evidence-based review (systematic map) of the developments within this field.
- Contribute to the development of emerging eco-technologies that have the capacity to turn nutrients and carbon into benefits (e.g. bio-energy, fertilizers), by providing an encompassing framework and platform for rigorous testing and analysis.

- Development of decision support systems for sustainable eco-technologies in the BSR.
- Contribute to better assessment of eco-technology efficiency via integrated and participatory modelling in three catchments areas in Finland, Sweden and Poland.
- Contribute to methodological innovation on application and adaptation of eco-technologies

2) Reduce knowledge gaps on policy performance, enabling/constraining factors, and costs and benefits of eco-technologies

- Assess the broader socio-cultural drivers linked to eco-technologies from a historical perspective
- Identify the main gaps in the policy environment constraining the implementation of emerging eco-technologies in the catchments around the Baltic Sea
- Inform policy through science on what works where and under which conditions through an evidence-based review (systematic map and systematic reviews) of eco-technologies and the regional economic and institutional structures in which these technologies evolve.

3) Provide a framework for improved systematic stakeholder involvement:

- Develop methods for improved stakeholder engagement in water management through participatory approaches in the case study areas in Sweden, Finland and Poland.
- Enact a co-enquiry process with stakeholders into opportunities for innovations in eco-technologies capable of transforming nutrients and pollutants into benefits for multiple sectors at different scales.
- Bring stakeholder values into eco-technology choices to demonstrate needs for adaptation to local contexts and ways for eco-technologies to efficiently contribute to local and regional developments.
- Disseminate results and facilitate the exchange of learning experiences, first within the three catchment areas, and secondly across a larger network of municipalities in the BSR.
- Establish new cooperative networks at case study sites and empower existing regional networks by providing information, co-organize events and engage in dialogues.

4) Support commercialization of eco-technologies:

- Identify market and institutional opportunities for eco-technologies that (may) contribute to resource recovery and reuse of nutrients, micro-pollutants and micro-plastics (e.g. renewable energy).
- Identify potential constraints and opportunities for integration and implementation of eco-technologies using economical models.
- Facilitate the transfer of eco-technologies contributing to win-win solutions to multiple and interlinked challenges in the BSR.
- Link producers of eco-technologies (small and medium enterprises - SMEs), to users (municipalities) by providing interactive platforms of knowledge exchange where both producers and users have access to RETURN's envisaged outputs, existing networks, and established methodologies and services.

5) Establish a user-driven knowledge platform and improve technology-user interface

- Develop an open-access database that maps out existing research and implementation of eco-technologies in the BSR. This database will be intuitive, also mapped out in an interactive geographical information system (GIS) platform, and easily managed so that practitioners, scientists and policy-makers can incorporate it in their practices
- Develop methodologies that enact the scaling of a systemic mix of eco-technological interventions within the highly diverse contexts that make up the BSR and allows for a deeply interactive media of knowledge.

1.2 Project Structure

BONUS RETURN is structured around 6 Work Packages that will be implemented in three river basins: The Vantaanjoki river basin in Finland, the Słupia river basin in Poland, and Fyrisån river basin in Sweden.

Work Package 1: Coordination, management, communication and dissemination.
Work Package 2: Integrated Evidence-based review of eco-technologies.
Work Package 3: Sustainability Analyses.
Work Package 4: Environmental Modelling.
Work Package 5: Implementation Support for Eco-technologies.
Work Package 6: Innovative Methods in Stakeholder Engagement.

1.1 Deliverable context and objective

The current deliverable (2.2) is part of WP 2. The objectives of WP 2 are to summarise the evidence relating to reuse of carbon and nutrients using ecotechnologies through the use of systematic mapping and systematic review methodology.

This deliverable summarises the initial systematic mapping[1] of studies in two systematic maps on ecotechnologies in agricultural contexts and municipal wastewater contexts for reuse of carbon and nutrients. Please see the draft systematic map protocol for these mapping exercises appended to this document. This protocol outlines the planned methods for the maps and the procedures enacted during the preparation of this deliverable.

1.2 Outline of the report

This report accompanies the spreadsheets that list identified ecotechnologies in the two sets of evidence (agriculture and municipal wastewater).

2 LIST OF ECOTECHNOLOGIES

Deliverable 2.2 represents the results of the initial mapping step of the systematic map, whereby 40% of the agricultural evidence and 60% of the wastewater evidence has been screened for relevance and coded, to date. This list of ecotechnologies is thus not a comprehensive list from the evidence base, but the evidence has been sorted randomly, such that this 40 and 60 percent is a representative sample of the evidence base as a whole. This methodology has enabled us to assess ecotechnologies whilst coding and mapping of evidence is ongoing. Deliverable 2.3 will include the final database of ecotechnologies and studies from 100% of each of the two sets of evidence. This deliverable is due to be completed later in 2018.

The results of this coding are available in the additional files (BONUSRETURN_D.2.2_List of agriculture ecotechnologies.xlsx and BONUSRETURN_D.2.2_List of municipal wastewater ecotechnologies.xlsx).

[1] A systematic map is a stepwise, a priori method for comprehensively, transparently and rigorously assessing the state of knowledge on a particular topic. See https://environmentalevidencejournal.biomedcentral.com/articles/10.1186/s13750-016-0059-6 for further details of the methodology.

Background
The degradation of the Baltic Sea is an ongoing problem, despite investments in measures to reduce external inputs of pollutants and nutrients from both diffuse and point sources. Available technological and management measures to curb eutrophication and pollution flows to the sea have not been adapted adequately to the contexts in which they are being applied. Furthermore, measures are often designed based on single objectives, thereby limiting opportunities for multiple benefits. In addition, there is a general sense that measures to address the deterioration of the Baltic ecosystem are primarily technologically-driven and lacking broader stakeholder acceptance, and the "experts" who define these measures have little engagement with industry, investors, civil society and authorities. This problem is exacerbated by governance and management taking place in sectoral silos with poor coordination across sectors. As a result, research shows that regional institutional diversity is presently a barrier to transboundary cooperation in the Baltic Sea Region (BSR) and that actions to achieve national environmental targets can compromise environmental goals in the BSR. The regional dimension of environmental degradation in the BSR has historically received weaker recognition in policy development and implementation locally. However, developments in recent years suggest a new trend with growing investments in environmental protection supporting social, economic, and territorial cohesion.

The term 'ecotechnology' has been used since the early 1970s to describe combinations of practices relating to the environment and technological intervention. Despite its common usage, there seems to be little consensus on its practical meaning, highlighting a difficulty in ensuring stakeholders understand the term. We have based our definition on a recent systematic review and thematic synthesis of the research literature (Haddaway et al. in press), which identified several key domains that must be described in any definition, including the type of technology, how it works, for whom and with what synergies across human and ecological domains. Our final definition is as follows:

> *"Eco-technologies are human interventions in social-ecological systems in the form of practices and/or biological, physical, and chemical processes designed to minimise harm to the environment and provide services of value to society"*

This definition encompasses both hard technologies and practices, and is hence very broad. The thematic synthesis by Haddaway et al. (in press) identified common use of the term 'ecotechnology' as a buzzword, with very few explicit definitions. As such we use a broad definition so as to remain conservative and broadly relevant.

Stakeholder Engagement
The topic for this review was initially proposed by the research funder BONUS (https://www.bonusportal.org/). The scope of the project was then refined through expert discussions as part of the process of drafting an application in response to the call by the research funder. Stakeholders, consisting of the broader BONUS RETURN consortium members, were involved in discussions of the scope and search strategy for the map.

Objectives
The primary question for this systematic map is: What evidence exists relating to potential ecotechnologies in agriculture and municipal wastewater systems for the reuse of nutrients in the Baltic Sea?

This review has so far identified a partially complete list of studies that focus on the effectiveness and efficacy of ecotechnologies for reusing carbon and nutrients (nitrogen and phosphorus) in the

Baltic Sea or in systems with direct relevance to the Baltic Sea environment. The ongoing systematic map will then complete this list.

In this project we have described all relevant studies in terms of the settings, the PICO elements (population(s), intervention(s), comparator(s) and outcome(s)) and methods in each study. The key outputs are as follows:

1. A comprehensive list of studied ecotechnologies used in the Baltic region.
2. A detailed database of studies and descriptive information.

Methods

Searching

Bibliographic databases

We have searched for evidence across Scopus and Web of Science Core Collections (consisting of the following indexed: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, and ESCI), using subscriptions from the Stockholm University Library. Searches were performed using English language search terms for two sets of searches across all bibliographic databases. See Additional File 1 for details of the search strings and their adaptations to different databases. The following search strings were used in bibliographic databases:

Municipal wastewater string: ("organic carbon" OR DOC OR "organic C" OR "organic matter" OR nutrient* OR nitrogen OR nitrate OR nitrite OR ammoni* OR phosphorus OR phosphate) AND (wastewater OR "waste water" OR "storm water" OR stormwater OR blackwater OR "black water" OR greywater OR "grey water" OR graywater OR "gray water" OR sludge OR septage OR sewage OR "organic waste*" OR "septic sludge" OR sewerage* OR digestate* OR "toilet waste") AND (return* OR recover* OR conver* OR circul* OR reus* OR recycl*)

Agriculture string: (recycl* OR reus* OR circul* OR conver* OR recover* OR return*) AND (agr* OR farm* OR crop* OR livestock OR "live stock" OR manure OR animal OR cultivat*) AND ("organic carbon" OR DOC OR "organic C" OR "organic matter" OR nutrient* OR nitrogen OR nitrate OR nitrite OR ammoni* OR phosphorus OR phosphate)

Searches in bibliographic databases were restricted in timescale to the period 2013 to 2017. This is to ensure that technological innovations are identified that have not yet proceeded to the business market.

Grey literature

Grey literature is identified in two ways. Firstly, through searches for evidence in Google Scholar, which has been shown to be effective in this respect (Haddaway et al. 2015). Secondly, searches will be performed across a suite of relevant organisational websites for ecotechnologies for the reuse of carbon and nutrients. Google Scholar searches were performed as part of the initial searching for this deliverable, whilst organisational website searching will be performed in latter stages of the mapping process and will feed into the third deliverable (2.3). Google Scholar searches were performed in English, whilst organisational website searches will be performed in English, Swedish, Finnish and Polish, representing many of the Baltic languages and constrained by the skillset and resources of the review team. Each organisational website is also hand searched for relevant publications.

Searches for grey literature will make use of terms related both to synonyms for ecotechnologies (e.g. 'eco-technology'), and combinations of outcome terms and reuse terms (e.g. 'carbon reuse').

The following websites will be searched in English. Additional organisational websites will be searched in non-English languages and this list will be constructed iteratively:

Website	Search language
1. Swedish Environmental Protection Agency (SEPA)	English
2. Swedish Board of Agriculture	English
3. The Swedish Agency for Marine and Water Management	English
4. Swedish directory of Master thesis (DiVA)	English
5. Foundation for Applied Water Research (STOWA)	English
6. Ekologgruppen i Landskrona AB	English
7. Danish Centre for Environment and Energy (DCE)	English
8. European Environment Agency (EEA)	English
9. Finnish Environment Institute (SYKE)	English
10. Federal Environment Agency (UmweltBundesAmt, Germany)	English
11. Leibniz Institute of Freshwater Ecology and Inland Fisheries, IGB (http://www.igb-berlin.de)	English

Google Scholar searches were restricted to articles published in the time period 2013 to 2017 as with bibliographic searches above. The first 1000 search results were extracted as citations using Publish or Perish software (https://harzing.com/resources/publish-or-perish) and introduced into the duplication removal and screening workflow alongside records from bibliographic databases. Remaining grey literature from organisational websites will be screened separately before being combined with other records.

<u>Testing comprehensiveness</u>

A benchmark list of 37 articles of known relevance to the review was screened against scoping search results to examine whether searches are able to locate relevant evidence. Any articles not found during scoping resulted in an examination of the search terms to identify why articles were missed and the search was adapted where necessary.

Screening

Results of the bibliographic searching were combined and duplicates removed prior to screening at title and abstract level (screened concurrently for efficiency). Potentially relevant records were then retrieved in full text (most commonly as PDF documents), tracking those that cannot be located or accessed and reporting this in the final review. Retrieved records were then screened at full text, with each record being assessed by one experienced reviewer.

<u>Inclusion criteria</u>

The following criteria were applied at all levels of screening:

Population(s): The Baltic region and environments with direct relevance to (similar environment with a high likelihood of transferability of ecotechnologies with a similar effect), including the waters of the Baltic Sea and the 'upstream' terrestrial environments in countries bordering the Baltic (Denmark, Estonia, Latvia, Finland, Germany, Lithuania, Poland, Russia, and Sweden). We consider all municipal wastewater environments to be relevant, but many agricultural contexts will not be relevant, hence the restriction.

Intervention(s): Any practice undertaken for the purposes of removing/capturing and reusing carbon and nutrients in waters or sediments with an outflow to a Baltic Sea-like environment. See above definition of 'ecotechnology' for further details.

Comparator(s): The presence of a comparator is not necessary but will be documented in the final systematic map database (Deliverable 2.3). Comparators include: none, before ecotechnology use, a control site without an ecotechnology, a comparison between different ecotechnologies, different intensities of the same ecotechnology, time series after ecotechnology implementation, before policy instrument, alternative policy instrument, absence of policy instrument, time series after policy implementation.

Outcome(s): Described reuse of carbon and nutrients from waters or sediments within or entering the Baltic Sea. Carbon outcomes include: soil carbon, soil organic carbon, total carbon, dissolved organic carbon, and organic matter, but also chemical oxygen demand and biological oxygen demand, which are proxies for carbon. Nutrient outcomes include: nitrogen compounds (nitrogen, nitrate, nitrite, ammonium) and phosphorus compounds (phosphorus, phosphate). Where reuse is not explicitly described within studies, we will include studies that describe storage or retention of carbon and nutrients where a clear reuse can be discerned from the information available.

Study type(s): Any study type will be eligible for inclusion, including literature reviews focusing on one or more ecotechnologies.

<u>Consistency checking</u>

Prior to commencing screening, consistency checking was performed with all reviewers on a subset of articles at both title and abstract level and full text level screening. A subset of between 100 and 700 title and abstract records and between 25 and 45 full text records was independently screened by all reviewers. These numbers represent approximately 10% of each set of results at each level for both searches. The results of the consistency checking were then compared between reviewers and all disagreements discussed in detail. Where the level of agreement was low (below c. 0.8 agreement), further consistency checking was performed on an additional set of articles and then discussed.

Critical appraisal

The validity of articles has not been appraised as part of this systematic map in accordance with accepted systematic mapping methodological guidance (James et al. 2016).

Data extraction

The following meta-data were extracted for all relevant studies:

- Ecotechnology name
- Short description
- Reused outcome
    - Carbon

  - Nutrients N
  - Nutrients P
- Type of reuse
  - Explicit, fully described reuse
  - Implicit or potential reuse

Meta-data extraction was performed by multiple reviewers following consistency checking on a parallel coding of subset of between 23 and 45 full texts, discussing all disagreements. The remaining full texts were then screened and coded.

Data synthesis and presentation
The evidence base identified within this systematic map is described primarily in detail within a systematic map database; a searchable spreadsheet with columns containing codes and meta-data related to the variables described in the meta-data extraction and coding schema, above.

3 REFERENCES

Haddaway NR, Collins AM, Coughlin D and Kirk S. The role of Google Scholar in evidence reviews and its applicability to grey literature searching. (2015) PloS one, 10(9), p.e0138237.
Haddaway NR, McConville J, Piniewski M. How is the term ‘ecotechnology’ used in the research literature? A systematic review with thematic synthesis. Ecohydrology and Hydrobiology (in press).

James KL, Randall NP, Haddaway NR, A methodology for systematic mapping in environmental sciences. (2016) Environmental Evidence, 5(1), p.7.